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Lockyer

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(54) **GAS TURBINE ENGINE COMPRESSOR WITH A BIASED INNER RING**

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F01D 17/16 (2006.01)
F01D 11/00 (2006.01)

(52) **U.S. Cl.**

CPC ***F04D 29/563*** (2013.01); ***F01D 17/162*** (2013.01); *F01D 11/001* (2013.01); *F05D 2300/501* (2013.01)

(58) **Field of Classification Search**

CPC F04D 29/563; F04D 29/66; F04D 29/668; F01D 5/10; F01D 5/16; F01D 5/26; F01D 25/04; F01D 25/06; F01D 25/164; F01D 17/162; F01D 17/167

USPC 415/148, 208.1, 151, 159, 160; 29/889.22

See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

2,671,634 A * 3/1954 Morley A01N 25/08 415/149.4
2,778,564 A * 1/1957 Halford F01D 17/162 138/46
3,542,484 A * 11/1970 Mason F01D 17/162 415/147
3,720,217 A * 3/1973 Matthews F02C 9/20 137/805
5,083,900 A 1/1992 Carletti et al.
6,767,183 B2 7/2004 Schilling et al.
7,445,427 B2 * 11/2008 Gutknecht F01D 17/162 415/160
8,038,387 B2 * 10/2011 Houradou F01D 17/162 384/215
2005/0276686 A1 12/2005 Bruce
2008/0031730 A1 2/2008 Houradou et al.
2013/0216359 A1 8/2013 Brandenburg et al.
2013/0259658 A1 * 10/2013 Dube F01D 5/10 415/148

FOREIGN PATENT DOCUMENTS

GB 2445863 A 7/2008

* cited by examiner

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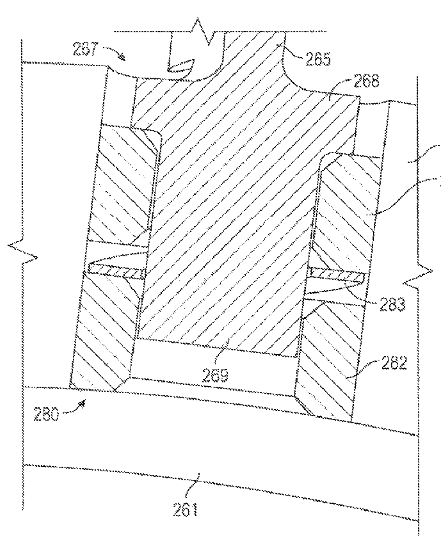
(57) **ABSTRACT**

An inner bushing assembly (**280**) to provide a biasing force between a guide vane (**260**) and an inner ring half (**261**) of a gas turbine engine compressor (**200**) is disclosed. The inner bushing assembly (**280**) includes a first bushing (**281**), a second bushing (**282**), and a biasing element (**283**). The first bushing (**281**) is configured to be installed about an inner vane shaft (**267**) of the guide vane (**260**) adjacent to an airfoil (**265**) of the guide vane (**260**). The second bushing (**282**) is configured to be installed about the inner vane shaft (**267**) distal to the airfoil (**265**). The biasing element (**283**) is configured to be installed about the inner vane shaft (**267**) between the first bushing (**281**) and the second bushing (**282**).

20 Claims, 4 Drawing Sheets



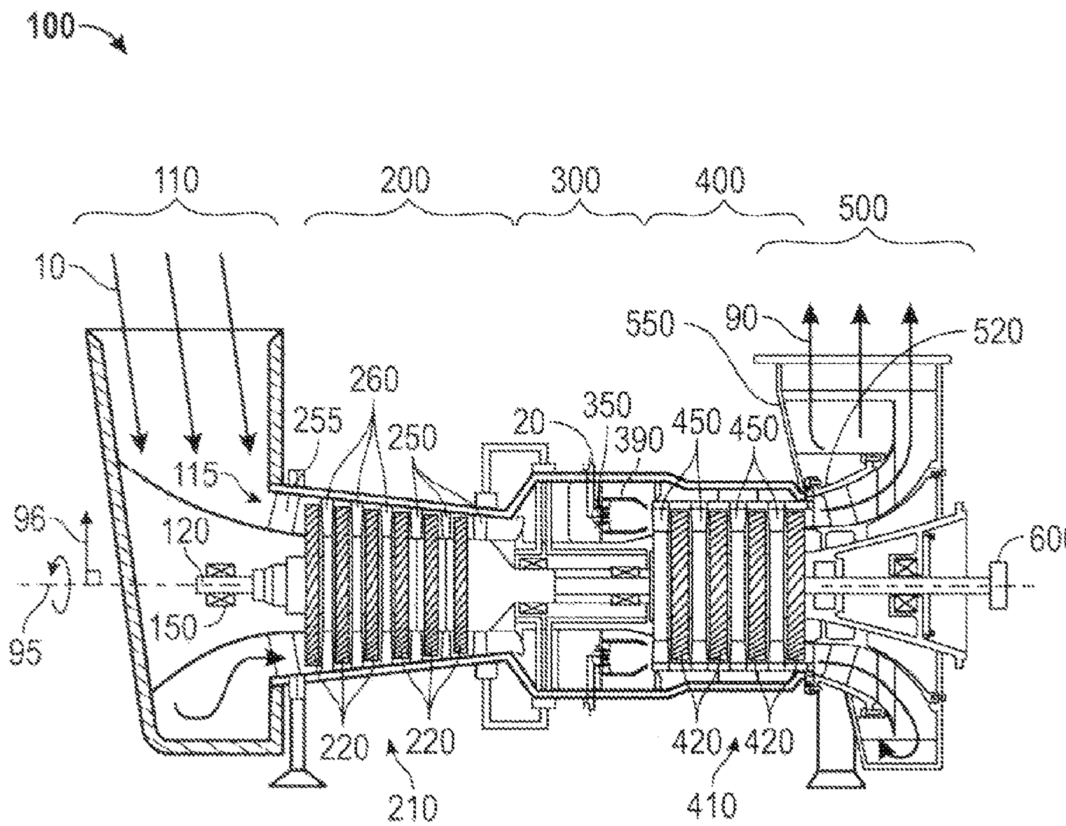

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FIG. 1

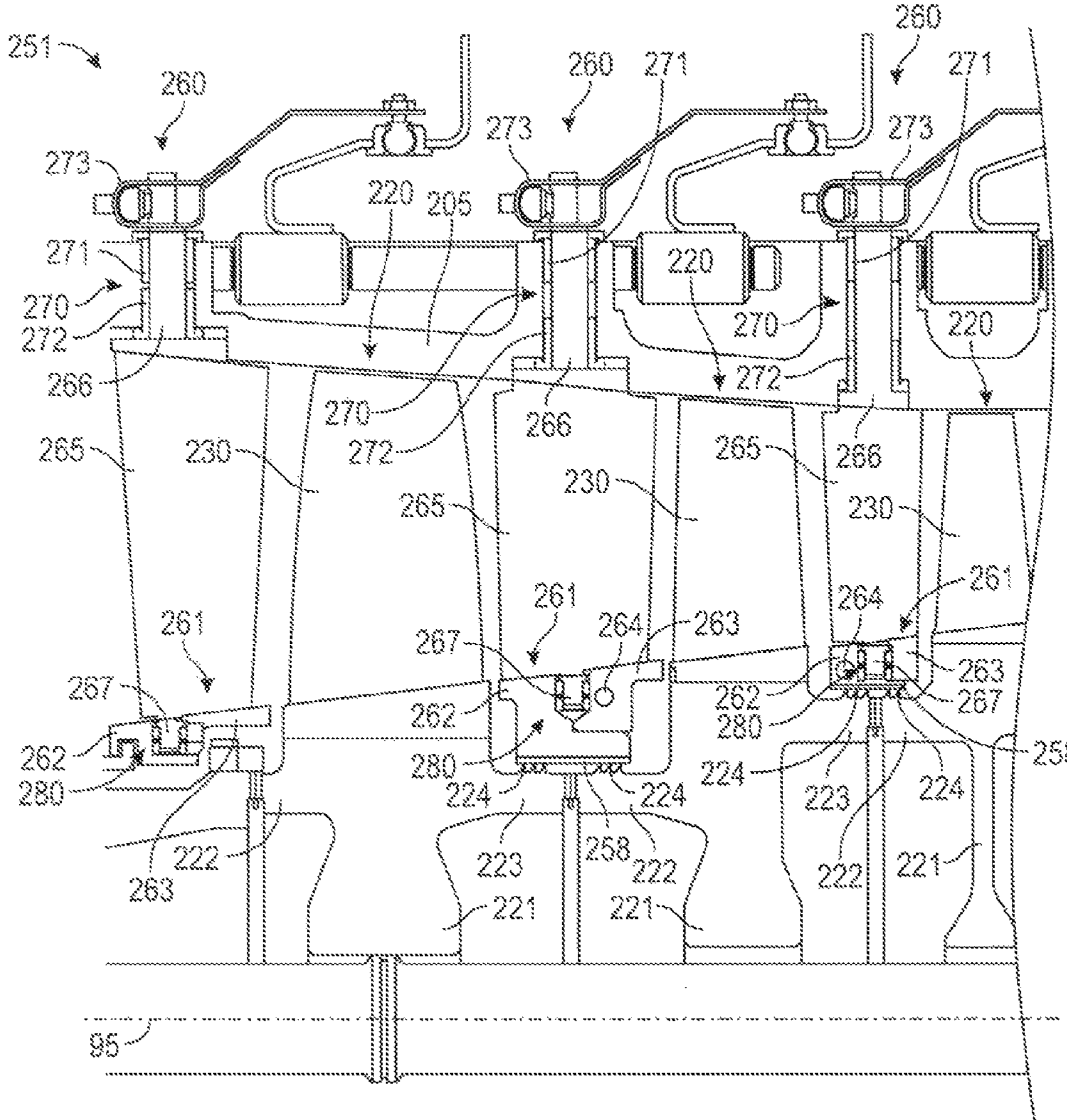
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FIG. 2

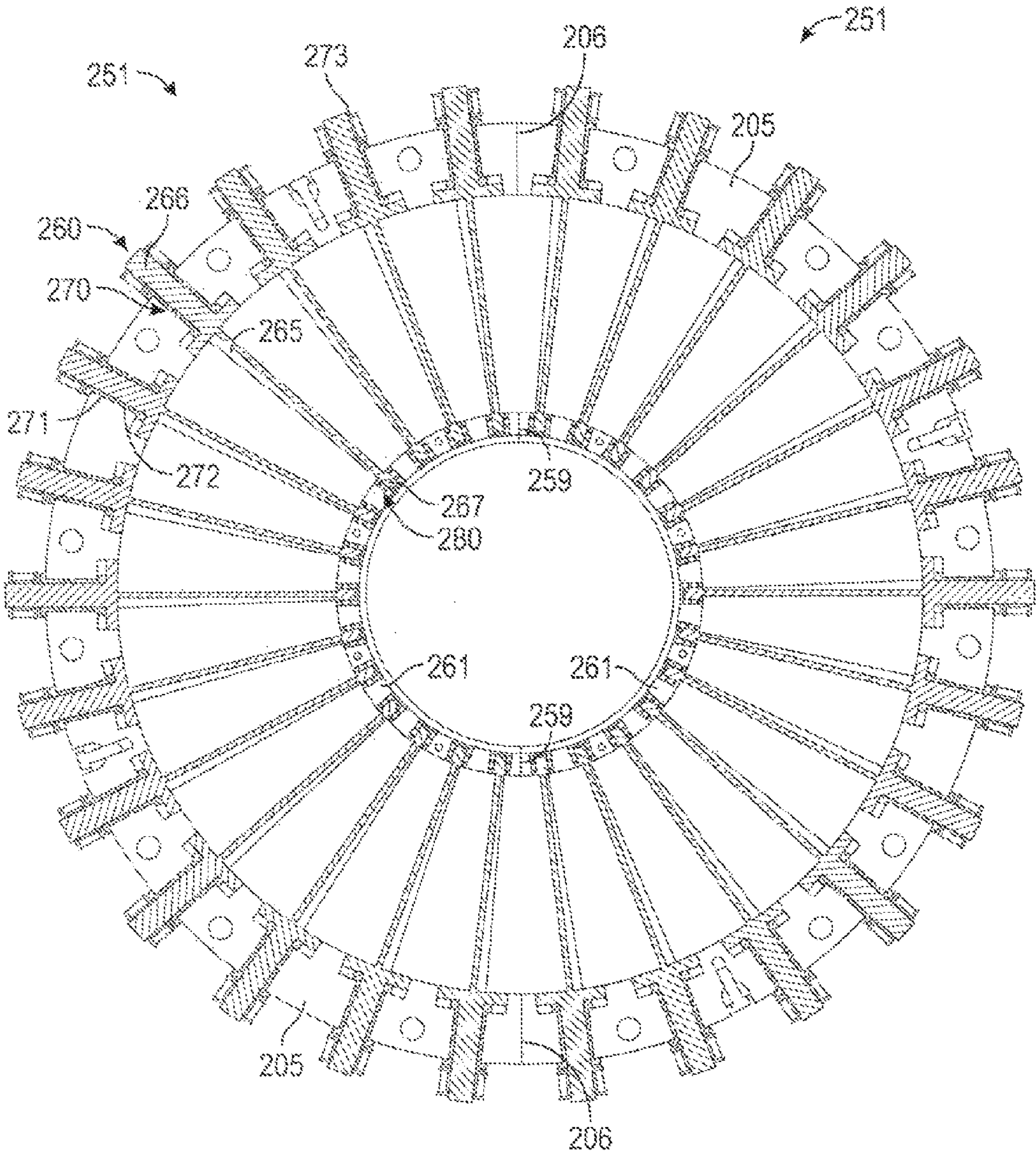

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FIG. 3

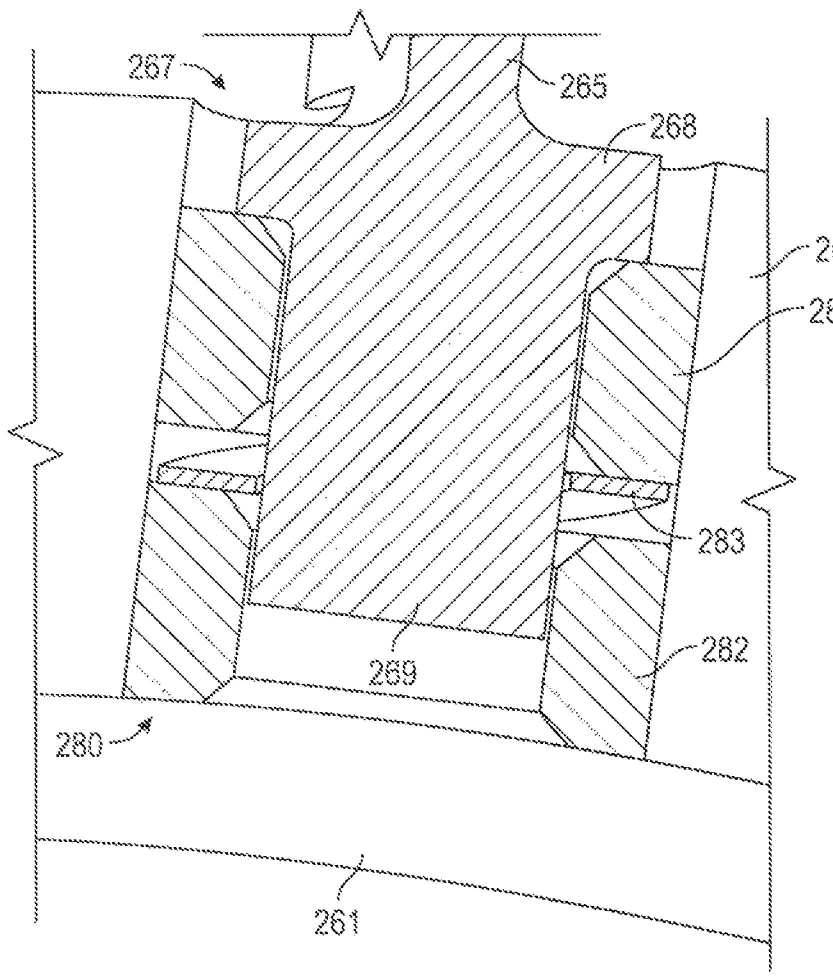

FIG. 4

GAS TURBINE ENGINE COMPRESSOR WITH A BIASED INNER RING

TECHNICAL FIELD

The present disclosure generally pertains to gas turbine engines, and is more particularly directed toward a compressor with a biased inner ring of a gas turbine engine.

BACKGROUND

Gas turbine engines include compressor, combustor, and turbine sections. The compressor may be built up in three assemblies: the compressor rotor assembly and two compressor stator assemblies. The compressor rotor assembly may be built up and balanced. The two compressor stator assemblies may be bolted together over the compressor rotor assembly. Portions of the assembly of the two compressor stator assemblies over the compressor rotor assembly may be blind.

U.S. patent application pub. No. 2008/0031730 to E. Houradou discloses a bearing for a turbomachine variable pitch stator vane pivot mounted in a bore of the turbomachine casing, and which comprises an inner busing secured to said pivot and an outer bushing secured to said bore, an elastomeric material being inserted between the inner bushing and the outer bushing to allow the vane to pivot about its axis and absorb at least some of the flexing of the pivot at right angles to the axis. The design makes it possible to reduce bearing bushing wear.

The present disclosure is directed toward overcoming one or more of the problems discovered by the inventors.

SUMMARY OF THE DISCLOSURE

An inner bushing assembly to a biasing force between a guide vane and an inner ring half of a gas turbine engine compressor is disclosed. The inner bushing assembly includes a first bushing, a second bushing, and a biasing element. The first bushing is configured to be installed about an inner vane shaft of the guide vane adjacent to an airfoil of the guide vane. The second bushing is configured to be installed about the inner vane shaft distal to the airfoil. The biasing element is configured to be installed about the inner vane shaft between the first bushing and the second bushing.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic illustration of an exemplary gas turbine engine.

FIG. **2** is a cross-sectional view of a portion of the gas turbine engine compressor of FIG. **1**.

FIG. **3** is an axial crass-section of two compressor suitor assemblies of the compressor of FIG. **2**.

FIG. **4** is cross-sectional view of an inner bushing assembly of FIG. **3**.

DETAILED DESCRIPTION

The systems disclosed herein include a gas turbine engine compressor with a compressor stator assembly. In embodiments, the gas turbine engine compressor stator assembly includes two compressor stator assembly halves. Each compressor stator assembly half includes variable guide vanes, inner bushing assemblies, and an inner ring. Each inner bushing assembly includes a biasing element. Each inner bushing assembly may react against a variable guide vane and the inner ring to center and clamp the two halves of the inner ring together. Centering and clamping the inner ring may increase the efficiency of the gas turbine engine and may reduce wear on the inner ring.

FIG. **1** is a schematic illustration of an exemplary gas turbine engine. Some of the surfaces have been left out or exaggerated (here and in other figures) for clarity and ease of explanation. Also, the disclosure may reference a forward and an aft direction. Generally, all references to "forward" and "aft" are associated with the flow direction of primary air (i.e., air used in the combustion process), unless specified otherwise. For example, forward is "upstream" relative to primary air flow, and aft is "downstream" relative to primary air flow.

In addition, the disclosure may generally reference a center axis **95** of rotation of the gas turbine engine, which may be generally defined by the longitudinal axis of its shaft **120** (supported by a plurality of bearing assemblies **150**). The center axis **95** may be common to or shared with various other engine concentric components. All references to radial, axial, and circumferential directions and measures refer to center axis **95**, unless specified otherwise, and terms such as "inner" and "outer" generally indicate a lesser or greater radial distance from, wherein a radial **96** may be in any direction perpendicular and radiating outward from center axis **95**.

A gas turbine engine **100** includes an inlet **110**, a shaft **120**, a gas producer or "compressor" **200**, a combustor **300**, a turbine **400**, an exhaust **500**, and a power output coupling **600**. The gas turbine engine **100** may have a single shaft or a dual shaft configuration.

The compressor **200** includes a compressor rotor assembly **210** and two compressor stator assembly halves **251**. The compressor rotor assembly **210** mechanically couples to shaft **120**. As illustrated, the compressor rotor assembly **210** is an axial flow rotor assembly. The compressor rotor assembly **210** includes one or more compressor disk assemblies **220**. Each compressor disk assembly **220** includes a compressor disk **221** (shown in FIG. **2**) that is circumferentially populated with compressor rotor blades **230** (shown in FIG. **2**).

Each compressor stator assembly half **251** includes compressor stationary vanes ("stators") **250**, half of compressor case **205**, and inlet guide vanes **255**. Each compressor stator assembly half **251** can include multiple sets of stators **250**. Each set may include half of the stators **250** of a compressor stage. Compressor stator assembly halves **251** are coupled together at compressor case **205** around compressor rotor assembly **210**. Compressor case **205** may include compressor case split lines **206** (shown in FIG. **3**). Stators **250** axially follow each of the compressor disk assemblies **220**. Each compressor disk assembly **220** paired with the adjacent stators **250** that follows the compressor disk assembly **220** is considered a compressor stage. Compressor **200** includes multiple compressor stages. Stators **250** may be variable guide vanes **260**. Inlet guide vases **255** may also be variable guide vanes **260**.

The combustor **300** includes one or more injectors **350** and includes one or more combustion chambers **390**.

The turbine **400** includes a turbine rotor assembly **410** and turbine nozzles **450**. The turbine rotor assembly **410** mechanically couples to the shaft **120**. As illustrated, the turbine rotor assembly **410** is an axial flow rotor assembly. The turbine rotor assembly **410** includes one or more turbine disk assemblies **420**. Each turbine disk assembly **420** includes a turbine disk that is circumferentially populated with turbine blades. Turbine nozzles **450** axially precede each of the turbine disk assemblies **420**. Each turbine disk assembly **420** paired with the adjacent turbine nozzles **450** that precede the turbine disk assembly **420** is considered a turbine stage. Turbine **400** includes multiple turbine stages.

The exhaust **500** includes an exhaust diffuser **520** and an exhaust collector **550**.

FIG. **2** is a cross-sectional view of a portion of the compressor **200** of FIG. **1**. In the embodiment shown, each of the three stator sections includes variable guide vanes **260**. In another embodiment the first four stages include variable guide vanes **260**. However, any number of compressor stages may include variable guide vanes **260**.

FIG. **3** is an axial cross-section of two compressor stator assembly halves **251** of FIG. **2** shown assembled in isolation from other compressor **200** assemblies. Referring to FIGS. **2** and **3**, each compressor stator assembly half **251** may include one or more inner ring halves **261**, one or more sets of variable guide vanes **260**, outer bushings **270**, inner bushing assemblies **280**, and curved springs **273**. Each inner ring half **261** is located radially inward from compressor case **205**. The inner ring split lines **259** between assembled inner ring halves **261** may be at 12:00 o'clock and 6:00 o'clock. Inner ring split lines **259** circumferentially align with compressor case split lines **206**. As illustrated in FIG. **2**, each inner ring half **261** includes a forward ring **262** and an aft ring **263**. In the embodiment shown in FIG. **2**, the compressor stator assembly half **251** includes three sets of variable guide vanes **260** and three inner ring halves **261**. Each inner ring half **261** is paired with one set of variable guide vanes **260**.

Referring to FIG. **2**, each inner ring half **261** may include dowels **264**. Dowels **264** may be located on the end surfaces of each inner ring half **261**. Each dowel may be located on the forward ring **262** or the aft ring **263**. Each dowel **264** may be a dowel pin or a dowel hole. The dowel pin being a cylindrical pin extending out from an end surface of an inner ring half **261** and the dowel hole being a cylindrical blind hole extending into an inner ring half **261** from an end surface of the inner ring half **261**.

Referring again to FIGS. **2** and **3**, each variable guide vane **260** may include an airfoil **265**, an outer vane shaft **266**, and an inner vane shaft **267**. Each airfoil **265** may extend between compressor case **205** and an inner ring half **261**. Outer vane shaft **266** may extend radially outward from airfoil **265** through compressor case **205**. Inner vane shaft **267** may extend radially inward from airfoil **265** into an inner ring half **261**. Inner vane shaft **267** may not extend through the inner ring half **261**.

FIG. **4** is a cross-sectional view of one embodiment of the inner bushing assembly **280** of FIG. **3**. Each inner vane shaft **267** has a T-shaped cross-section and includes a collar portion **268** adjacent the air foil **265** and a shaft portion **269** extending from the collar portion **268** away from the airfoil **265**.

Inner bushing assembly **280** may be located about shaft portion **269** radially between collar portion **268** and an inner ring half **261**. Collar portion **268** and the inner ring half **261** may trap inner bushing assembly **280** in place. The inner hushing assembly **280** can be a split bushing and includes a first bushing **281**, a second hushing **282**, and a biasing element **283**. The biasing element **283** provides force in the radial direction. First bushing **281** is located adjacent to collar portion **268**. Second bushing **282** is located proximal to first bushing **281**, distal to collar portion **268**. First bushing **281** and second bushing **282** may be manufactured from thermoplastics such as Imilon **514**. First bushing **281** and second bushing **282** may each have a cylindrical shape configured with a bore and sized to receive shaft portion **269**. The top and bottom edges of first bushing **281** and second bushing **282** that are adjacent to the bore may be chamfered.

Biasing element **283** is located between first bushing **281** and second bushing **282**. Alternatively, a single bushing may be used with an adjacent biasing element. The adjacent biasing element may be located radially inward or radially outward from the single bushing to provide a force in the radial direction. In the embodiment shown in FIG. **4**, biasing element **283** is a spring washer, such as a wave waster or a curved spring washer. In one embodiment, the wave washer has three convolutions.

Referring to FIGS. **2** and **3**, outer bushing **270** may be located about outer vane shaft **266** and radially within compressor case **205**. Outer bushing **270** may also be a split bushing including a third bushing **271** and a fourth bushing **272**. Fourth bushing **272** may be proximal to airfoil **265**. Third bushing **271** may be proximal to fourth bushing **272**, distal to airfoil **265**. Third bushing **271** and fourth bushing **272** may have a radial clearance there between.

As illustrated in FIGS. **2** and **3**, outer vane shaft **266** may extend from airfoil **265** beyond outer bushing **270** and compressor case **205**. Curved spring **273** may be attached to outer vane shaft **266** adjacent to compressor case **205** at the end of outer vane shaft **266** distal to airfoil **265**.

Referring now to FIG. **2**, each compressor disk **221** is coupled to shaft **120** and may include a forward wing **222**, an aft wing **223**, and labyrinth teeth **224**. Forward wing **222** may extend axially forward and aft wing **223** may extend axially aft. The forward wing **222** of a compressor disk **221** may contact the aft wing **223** of an adjacent compressor disk **221** radially inward of inner ring halves **261**. Labyrinth teeth **224** may extend radially outward from forward wing **222** and aft wing **223** towards inner ring halves **261**. Each inner ring half **261** may include labyrinth running surface **258** adjacent labyrinth teeth **224**.

As previously mentioned, each compressor disk **221** may be circumferentially populated with compressor rotor blades **230**. Compressor rotor blades **230** extend radially outward from compressor disk **221**. A portion of compressor case **205** may shroud compressor rotor blades **230** proximal the tips of the compressor rotor blades **230**.

One or more of the above components (or their subcomponents) may be made from stainless steel and/or durable, high temperature materials known as "superalloys". A superalloy, or high-performance alloy, is an alloy that exhibits excellent mechanical strength and creep resistance at high temperatures, good surface stability, and corrosion and oxidation resistance. Superalloys may include materials such as HASTELLOY, INCONEL, WASPALOY, RENE alloys, HAYNES alloys, INCOLOY, MP98T alloys, and CMSX single crystal alloys.

INDUSTRIAL APPLICABILITY

Gas turbine engines may be suited for any number of industrial applications such as various aspects of the oil and gas industry (including transmission, gathering, storage, withdrawal, and lifting of oil and natural gas), the power generation industry, cogeneration, aerospace, and other transportation industries.

Referring to FIG. **1**, a gas (typically air **10**) enters the inlet **110** as a "working fluid", and is compressed by the compressor **200**. In the compressor **200**, the working fluid is compressed in an annular flow path **115** by the series of compressor disk assemblies **220**. In particular, the air **10** is compressed in numbered "stages", the stages being associated with each compressor disk assembly **220**. For example, "4th stage air" may be associated with the 4th compressor disk assembly **220** in the downstream or "aft" direction, going from the inlet **110** towards the exhaust **500**). Likewise, each turbine disk assembly **420** may be associated with a numbered stage.

Once compressed air **10** leaves the compressor **200**, it enters the combustor **300**, where it is diffused and fuel **20** is added. Air **10** and fuel **20** are injected into the combustion chamber **390** via injector **350** and ignited. After the combustion reaction, energy is then extracted from the combusted fuel/air mixture via the turbine **400** by each stage of the series of turbine disk assemblies **420**. Exhaust gas **90** may then, be diffused in exhaust diffuser **520** and collected, redirected, and exit the system via an exhaust collector **550**. Exhaust gas **90** may also be further processed (e.g., to reduce harmful emissions, and/or to recover heat from the exhaust gas **90**).

During assembly of the compressor **200**, the compressor rotor assembly **210** may be coupled to shaft **120**. Each compressor stator assembly half **251** is assembled working outside in, from half of the compressor case **205** to inner ring half **261**. Outer bushings **270**, airfoils **265**, and curved springs **273** may be coupled to half of compressor case **205**. After inner bushing assemblies **280** are assembled onto inner vane shafts **267**, a forward, ring **262** and an aft ring **263** are coupled to airfoils **265** about inner vane shafts **267** and inner bushing assemblies **280**.

The two compressor stator assembly halves **251** may be placed around compressor rotor assembly **210** and shaft **120**. The compressor case **205** is then coupled together at compressor case split lines **206**. In one embodiment, bolts are used to couple the compressor case **205**. The assembly of the inner ring halves **261** of the two compressor stator assembly halves **251** may be a blind assembly. During assembly of the two compressor stator assembly halves **251** around compressor rotor assembly **210** the inner ring halves **261** of each compressor stator assembly half **251** may not be visible. Dowels **264** located on the end surfaces of each inner ring half **261** may guide the inner ring halves **261** together as the two compressor stator assemblies are joined together. Dowel pins of one inner ring half **261** may insert into dowel holes of the other inner ring half **261**.

Referring to FIG. **3**, the inner ring halves **261** may not be clamped or bolted together due to the blind assembly. The inner ring halves **261** may separate, which may decrease efficiency due to air to leak through the inner ring split lines **259**. The separation may also increase due clearance between the inner ring halves **261** and the labyrinth teeth **224**, which may decrease efficiency due to air leak through the labyrinth seal. Inner ring halves **261** may shift positions causing rubs during break-in or operation of the gas turbine engine **100**.

Inconsistencies in the position of inner ring halves **261** relative to labyrinth teeth **224** may cause lockup issues during testing and engine break-in which may cause test delays and possible engine down time for gas turbine engine operators. Lockup may occur during a hot engine restart due to rotor bow and misalignment of engine components such as inner ring halves **261**. Contact between inner ring halves **261** and labyrinth teeth **224** may also result in scoring or gouging of inner ring halves **261**, which may reduce the operating life of the inner ring halves **261**.

Excess clearances due to the movement of inner ring halves **261** may cause variable guide vanes **260** to flutter. Fluttering of the variable guide vanes **260** may reduce the operating life of variable guide vanes **260** due to high cycle fatigue. Fluttering variable guide vanes may cause an unsteady flow across multiple stages of the compressor and may cause compressor rotor blades **230** to flutter. Fluttering of the compressor rotor blades **230** may reduce die operating life of compressor rotor blades **230** due to high cycle fatigue.

Referring now to FIG. **4**, providing biasing element **283** can center each inner ring half **261** within compressor **200** and can clamp inner ring halves **261** together. Each inner bushing assembly **280** may react against a variable guide vane **260** and inner ring half **261** to center inner ring halves **261** and clamp inner ring halves **261** together. In the embodiment shown in FIG. **4**, each inner bushing assembly **280** may react against a collar portion **268**, which may provide a radial force to each inner ring half **261**, clamping inner ring halves **261** together.

The centering and clamping of inner ring halves **261** may prevent or reduce misalignment with labyrinth teeth **224**, which may prevent or reduce rubbing, scoring, and gouging. Preventing or reducing misalignment of inner ring halves **261** may also reduce or prevent air from leaking back through die labyrinth seal, which may increase efficiency. The centering and clamping of inner ring halves **261** may also prevent lockup of gas turbine engine **100**.

Eliminating or reducing excess clearance by preventing or reducing misalignment of inner ring halves **261** may eliminate or reduce the flutter of variable guide vanes **260** and compressor rotor blades **230**, which may increase the operating life of the variable guide vanes **260** and the compressor rotor blades **230**.

The preceding detailed description is merely exemplary in nature and is not intended to limit the invention or the application and uses of the invention. The described embodiments are not limited to use in conjunction with a particular type of gas turbine engine. Hence, although the present disclosure, for convenience of explanation, depicts and describes particular Compressor stator assembly halves and associated processes, it will be appreciated that other compressor stator assembly halves and processes in accordance with this disclosure can be implemented in various other compressor stages, configurations, and types of machines. Furthermore, there is no intention to be bound by any theory presented in the preceding background or detailed description. It is also understood that the illustrations may include exaggerated dimensions to better illustrate the referenced items shown, and are not consider limiting unless expressly stated as such.

What is claimed is:

1. An inner bushing assembly to provide a biasing force between a guide vane and an inner ring half of a gas turbine engine compressor, the inner bushing assembly comprising:
- a first bushing configured to be installed about an inner vane shaft of the guide vane adjacent to an airfoil of the guide vane;
- a second bushing configured to be installed about the inner vane shaft distal to the airfoil; and
- a biasing element configured to be installed about the inner vane shaft between the first bushing and the second bushing, the biasing element configured to separate the first bushing and the second bushing.

2. The inner bushing assembly of claim **1**, wherein the biasing element comprises a spring washer.

3. The inner bushing assembly of claim **2**, wherein the spring washer comprises a wave washer.

4. The inner bushing assembly of claim **3**, wherein the wave washer includes three convolutions.

5. The inner bushing assembly of claim **1**, wherein the first bushing comprises a thermoplastic and the second bushing comprises a thermoplastic.

6. A compressor stator assembly half for a gas turbine engine compressor, comprising:
- a plurality of variable guide vanes, each variable guide vane having
  - an airfoil, and
  - an inner vane shaft extending from the airfoil, the inner vane shaft including
    - a collar portion, and
    - a shaft portion;

a plurality of inner bushing assemblies, each inner bushing assembly having

a first bushing located about the shaft portion and adjacent the collar portion of one of the plurality of variable guide vanes,

a second bushing located about the shaft portion and distal to the collar portion of one of the plurality of variable guide vanes, and

a biasing element located about the shaft portion of one of the plurality of variable guide vanes and between the first bushing and the second bushing, the biasing element configured to separate the first bushing and the second bushing; and

an inner ring half coupled to the plurality of variable guide vanes.

7. The compressor stator assembly half of claim **6**, further comprising:

a half of a compressor case;

each variable guide vane further having

an outer vane shaft extending from the airfoil distal to the inner vane shaft extending through the compressor case;

a plurality of outer bushings, each outer bushing is located within the half of the compressor case and about the outer vane shaft of one of the plurality of variable guide vanes; and

a plurality of curved springs located adjacent to the compressor case attached to an end of the outer vane shaft distal the airfoil of one of the plurality of variable guide vanes.

8. The compressor stator assembly half of claim **7**, further comprising a plurality of inlet guide vanes, wherein each inlet guide vane is a variable guide vane.

9. The compressor stator assembly half of claim **6**, wherein the inner ring half includes a forward ring and an aft ring.

10. The compressor stator assembly half of claim **6**, wherein the biasing element comprises a spring washer.

11. The compressor stator assembly half of claim **10**, wherein the spring washer comprises a wave washer.

12. The compressor stator assembly half of claim **11**, wherein the wave washer includes three convolutions.

13. The compressor stator assembly half of claim **6**, wherein the first bushing comprises a thermoplastic and the second bushing comprises a thermoplastic.

14. A gas turbine engine including two compressor stator assembly halves of claim **6**, wherein the compressor stator assembly halves are coupled together about a compressor rotor assembly.

15. A compressor stator assembly half for a gas turbine engine compressor, comprising:

a plurality of variable guide vanes, each variable guide vane having

an airfoil, and

an inner vane shaft extending from the airfoil, the inner vane shaft including

a shaft portion, and

a collar portion adjacent to the airfoil;

an inner ring half coupled to the plurality of variable guide vanes about each inner vane shaft; and

a plurality of inner bushing assemblies, each inner bushing assembly having

a first bushing located about the shaft portion and adjacent the collar portion of one of the plurality of variable guide vanes,

a second bushing located about the shaft portion and distal to the collar portion of one of the plurality of variable guide vanes, and

a biasing element located about the shaft portion of one of the plurality of variable guide vanes and between the first bushing and the second bushing, the biasing element configured to separate the first bushing and the second bushing, wherein the biasing element provides a radial force to the inner ring half.

16. The compressor stator assembly half of claim **15**, further comprising:

a half of a compressor case;

each variable guide vane further having

an outer vane shaft extending from the airfoil distal to the inner vane shaft extending through the compressor case;

a plurality of outer bushings, each outer bushing is located within the half of the compressor case and about the outer vane shaft of one of the plurality of variable guide vanes; and

a plurality of curved springs located adjacent to the compressor case attached to an end of the outer vane shaft distal the airfoil of one of the plurality of variable guide vanes.

17. The compressor stator assembly half of claim **15**, wherein the biasing element comprises a spring washer.

18. The compressor stator assembly half of claim **15**, wherein the spring washer comprises a wave washer.

19. The compressor stator assembly half of claim **15**, wherein each inner bushing assembly is installed onto the shaft portion of one of the inner vane shafts between the collar portion and the inner ring half.

20. A gas turbine engine including two compressor stator assembly halves of claim **15**, wherein the compressor stator assembly halves are coupled together about a compressor rotor assembly.

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